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Does Europe perform too little corporate R&D? A comparison of EU and non-EU corporate R&D performance

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ABSTRACT

This paper examines whether there are significant differences in private R&D investment performance between the EU and the US and, if so, why. The study is based on data from the 2008 EU Industrial R&D Investment Scoreboard. The investigation assesses the effects of three very distinct factors that can determine the relative size of the overall R&D intensities of the two economies: these are the influence of sector composition (*structural effect*) vis-à-vis the intensity of R&D in each sector (*intrinsic effect*) and company demographics. The paper finds that the lower overall corporate R&D intensity for the EU is the result of sector specialisation (*structural effect*) – the US has a stronger sectoral specialisation in the high R&D intensity (especially ICT-related) sectors than the EU does, and also has a much larger population of R&D investing firms within these sectors. Since aggregate R&D indicators are so closely dependent on industrial structures, many of the debates and claims about differences in comparative R&D performance are in effect about industrial structure rather than sectoral R&D performance. These have complex policy implications that are discussed in the closing section.

1. Introduction

1.1. *Comparative R&D expenditure performance: a policy issue?*

Research and Development (R&D) expenditures have long been an important concern for innovation analysts, who have used them as a proxy for innovation inputs and as a determinant of productivity growth. Perhaps, as a consequence, governments have increasingly seen R&D policy as an instrument for achieving their wider objectives related to growth, productivity and competitiveness. One effect of this is that many governments, as well as the EU as a whole, have established R&D intensity targets (for a comprehensive overview, see: Sheehan and Wyckoff (2003)). Some governments have brought in R&D tax credit schemes to encourage additional R&D investment and some of these schemes give tax relief based on an R&D intensity measure.

In the Lisbon strategy – which seeks to make the EU 'the most competitive knowledge-based economy' – the EU formulated a commitment to higher levels of R&D intensity as well as to changes in R&D organisation and framework conditions. Such objectives rest partly on proposals to increase publicly-funded R&D, but also emphasise the need for significant increases in business-funded R&D. The EU's aim in doing this is to approach and possibly surpass the effort made by competing economies (particularly the US). In fact, as Soete (2006) put it in an interesting paper, while Europe has kept up with the US in investing public resources in knowledge, both in higher education and research, the EU has dramatically failed to convince the private sector and its citizens to invest in knowledge, the key to its own long-term future.

Building on the Lisbon objective, the 2002 Barcelona European Council set a target for EU R&D of 3% of EU GDP, of which 2/3 should be financed by the private sector (European Commission, 2003).

These targets are appealing and enticingly easy to grasp. However, they are even more easily misunderstood because aggre-

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gate R&D numbers for countries or regions are not simply an effect of R&D 'effort': they are a combined outcome of company strategies, company demographics, industrial structures, and macro-economic dynamics (Soete, 2005).

A complete model of these determinants of R&D expenditure would probably be very complex indeed (see for example Jaumotte and Pain (2005) and Falk (2004) for relevant modelling efforts). It is important to keep these underlying issues in mind when thinking about the appropriateness of particular policy strategies, and about whether and how specific targets for R&D expenditure or R&D intensity might be reached. A common approach is to distinguish between 'intrinsic' and 'structural' factors in shaping R&D intensity: intrinsic factors reflect within-sector effort, while structural factors reflect the size of R&D-intensive sectors in relation to other sectors within an economy. Low aggregate R&D intensity can simply reflect the absence or small size of R&D-intensive sectors (or the very large relative size of sectors with high sales but relatively low R&D such as oil & gas), rather than any general failure of R&D performance (Griffith and Harrison, 2003, for example, have recently shown that the UK's low aggregate R&D intensity largely reflects structural factors).

1.2. Aim and research questions

This article aims to investigate the differences in private-sector R&D investment between EU companies and their competitors in other major economies. It utilises recent company data to identify structural and specialisation characteristics that explain the sizeable differences in aggregate R&D intensity observed between two populations of companies (EU and non-EU ones).[1] The specific research question guiding our investigation is whether the explanation for the lower overall corporate R&D intensity of the EU vis-à-vis the US and Japan is mainly because of lower EU R&D intensities across a wide range of sectors or because the structure of the EU economy has a larger relative share of low R&D intensity sectors and hence a smaller share of high intensity sectors. In other words, does the explanation lie mainly in an "intrinsic" vs. a "structural" effect? This study also investigates the distributions of R&D and R&D intensity for the three main world regions as well as the demographics of R&D-intensive firms to investigate whether these effects play a role in determining the differences in overall R&D intensity between these different world regions. Finally, the study analyses the possible consequences of these findings for policy-making.

1.3. Structure of the paper

The paper is organised as follows:

After the above introduction, Section 2 briefly reviews the main findings and relevance of benchmarking private R&D investment performance within the literature on "Economics of Research and Innovation".

Section 3 provides an overview of the tools used to benchmark R&D investment as well as presenting the data used in this study, namely the R&D investment of a large set of firms derived from the information listed in their annual accounts.

Section 4 investigates the distribution of R&D by comparing R&D across different sector groups using R&D intensity levels (following a widely-used approach to characterise industrial sectors according to their technological activity as measured by their level of R&D intensity).

This is followed by Section 5 which introduces the methodology to decompose R&D intensity into 'structural' and 'intrinsic' effects, within the major economies under study. This method of decomposition is then applied to an extensive set of company R&D data; key features are discussed and the results for the main economies compared.

Following this, Section 6 analyses the distribution of R&D across top R&D investing firms to examine R&D intensity by company size to see if differences in this contribute to differences between world regions.

Finally, Section 7 sums up the main findings and offers some concluding remarks relevant to policy-making.

2. Industrial R&D investment performance in the EU

This section sets out the conceptual framework reliably anchored to the published economic literature and highlights why the nature and causes of the EU private R&D investment performance profile matter and why they are important for policy-making. It also briefly reviews the relevance of benchmarking private R&D investment performance within the literature on the "Economics of Research and Innovation".

2.1. Why private R&D investment performance matters

Economic theory (Solow, 1957) points to technical change as the major source of productivity growth in the long run. R&D is a major source of technical change (Romer, 1990; Guellec and van Pottelsberghe de la Potterie, 2001) and this is recognised as a key element for increasing the knowledge base and, with it, the growth, productivity and competitiveness of an economy (Coccia, 2008; Mowery and Rosenberg, 1989).

As a matter of fact, most of the arguments that provide justification for policies targeted at raising the level and efficiency of R&D rely on the assumption of close links between R&D spending and micro- and macro-economic performance (Kafouros, 2008; Bilbao-Osorio and Rodríguez-Pose, 2004; Griffith et al., 2004; Mitchell, 1999).

It follows that, given the role played by competitive innovation-led enterprises in the economy (i.e. the return in terms of economic and social benefits), policy initiatives do not aim at raising the level of private R&D *per se*, but aim at making R&D investment more effective and at overcoming possible barriers to innovation and hence to economic and social prosperity (Pessoa, 2007; Soete, 2007; Jones and Williams, 1998).

It is not our intention to debate here whether, in order to address the EU R&D investment deficit to achieve a knowledge-intensive economy and society, the EU needs a long-term, structured industrial policy or simply short-term policy actions that address one-by-one the different market failures which impede the scale, effectiveness and impact of R&D investment.

We are however convinced that, within this context, it is important to understand and describe the nature and characteristics of the EU's deficit in R&D intensity and performance since this would guide the shape and effectiveness of whatever R&D-related policies and means might be employed.

2.2. The EU R&D intensity deficit: nature and reasons

There is extensive literature that deals with the deficit in the EU's overall company R&D intensity compared to that of competing economies and the various factors that could determine it. For instance, there are many scientific papers that consider firms'

[1] The study relies on data on industrial R&D performance: the "EU Industrial R&D Investment Scoreboard". Its most updated version contains R&D investment and company performance data of the 1000 largest R&D performing enterprises in the EU and 1000 in the non-EU (European Commission, 2008b).

demography, size and dynamics (capacity for rapid growth) as factors that may influence the deficit.

Bartelsman et al. (2003) conducted an analysis, based on a dataset of sectoral indicators of firm dynamics at country level and information from business records. They conclude that post entry performance differs markedly between Europe and the US (it is higher in the US), while O'Sullivan (2007) cite the lack of growth of new, technology-based firms in the EU as one of the causes of the EU R&D intensity deficit. This finding is confirmed by the recent work of Ortega-Argilés and Brandsma (2008). They conducted an econometric analysis – including a series of regressions to test the regularities and differences shown in the descriptive analysis – of the EU–US differences in the size of R&D-intensive firms using a panel of data with 338 EU and 557 US firms and concluded that firm size plays a role in the overall R&D intensity gap, independent of the sectoral composition of R&D.

Besides the dynamics of firms and their size, there are also studies (e.g. Aghion, 2006; Cohen and Lorenzi, 2000) pointing out various framework conditions as additional causes contributing to the EU R&D intensity deficit. These include a less entrepreneurial culture, a more costly IPR regime, high taxation, more difficult access to finance and to adequate skills, costly social security regimes, overregulation of labour and capital markets, etc.

However, a large part of the scientific effort devoted to studying this phenomenon seems to address one main issue – i.e. the "*intrinsic*" vs. "*structural*" effect – and reaches two divergent conclusions. There is one group of researchers who are more inclined to consider that the EU R&D deficit is generally the result of companies' under-investment in R&D (*intrinsic effect*). Conversely, other researchers tend to conclude that the gap is manly due to the structure of the economy (*structural effect*).

Erken and van Es (2007) examined the differences in business R&D between 14 EU countries and the US in 36 sectors over a 17-year period using OECD-STAN and ANBERD data. They concluded that the contribution of the sector composition to the R&D funding gap between the EU and the US was very low, whereas the intrinsic effect was undoubtedly responsible for the private R&D gap. They also argued that, if only manufacturing sectors are taken into account, corporate R&D intensity does not differ much between the US and the EU. Rather, the size of high R&D intensity sectors (especially the larger size of the US ICT-related sectors) explains the difference in R&D expenditure between the manufacturing sectors of the US and the EU. However, the main conclusion of their work is that the European R&D shortfall is mainly caused by the negative intrinsic effect of the service sector, specifically citing comparability problems with R&D data for the services sector between the US and the EU.

Therefore, it is hardly surprising that another study, Mathieu and Van Pottelsberghe de la Potterie (2008), limits its analysis of R&D intensity to 20 manufacturing sectors, concluding that BERD intensity is mainly driven by the degree of specialisation in R&D-intensive industries. It therefore supports the argument in favour of a sectoral composition effect as the cause of the low EU R&D intensity. This study focused on 10 European member states using a panel of data that covered the period from 1991 to 2002; all the service sectors are treated as a single aggregate sector.

Van Ark et al. (2003) observed that U.S. expenditures on R&D outside the manufacturing sector have been increasing since the mid-1990s and now account for about a third of total R&D expenditure, up from less than one fifth in 1995. So, while the manufacturing sector accounts for the majority of R&D expenditure, its share is declining. They note that European growth in services R&D has been slower than in the US and has still not reached 20% of total R&D. At least part of this gap is probably reasonable since ICT diffusion has been slower in Europe than the US.

Several studies carried out in the last few decades investigate the reasons behind the commonly observed pattern of "falling behind" in the area of knowledge investments for Europe as a whole in relation to the US. For example, Pavitt and Soete (1982) found that one of the main factors that underlie this phenomenon was related to the strong increase in international specialisation in individual EU member countries.

The conclusions of these earlier studies are confirmed by other more recent studies such as those carried out by O'Sullivan (2007) and Ciupagea and Moncada-Paternò-Castello (2006), which suggest that the European private R&D investment deficit is mainly due to a sectoral composition effect.

In line with this finding, a paper from Lindmark et al. (2008), in which ETEPS (2007) micro-data as well as Eurostat, OECD, EU, KLEMS national statistics were used and EU and US R&D intensities were decomposed, concludes that the R&D intensities of companies are very similar, but the sector composition is very different. The study found the R&D intensity difference was caused by the smaller size of the ICT sector in the EU compared to the US. In fact, the ICT sector in the EU also contributes much less to overall business expenditure in R&D in relative terms than does to its counterpart in the US. This conclusion confirms the findings of O'Sullivan (2007), GFII (2007) and the European Commission (2007, 2008a).

In this context, it should be emphasised that the high-tech sectors are important not only because companies in them invest at a higher R&D intensity but also because, in such sectors, the link between R&D and productivity turns out to be greater and more significant (Ortega-Argilés et al., 2009a).

In summary, the divergent findings in the literature concerning the causes of the R&D intensity gap between EU and US companies suggest caution should be exercised when drawing general conclusions based on individual studies. Some methodological problems make it difficult to converge on generally-accepted measures of structural and intrinsic effects. The results of decomposing the R&D deficit into these two components have been shown to be highly sensitive to the level of detail at which industries are compared (Jaumotte and Pain, 2005). Furthermore, the divergence of results also seems to be dependent on whether or not service sectors are taken into consideration together with manufacturing. More importantly, in the case of studies considering both manufacturing and service sectors, the results lack robustness because of the widely recognised comparability problems for service sector R&D data between the US and the EU, which are subject to very different statistical norms (Erken and van Es, 2007; Duchêne et al., 2009). Moreover, the conclusions of these studies cannot necessarily be applied to all countries and all economies because of the possible heterogeneity in R&D intensities and industrial structures: '*intrinsic*' may dominate in some countries while '*structural*' dominates in others.

The present paper seeks to improve understanding of the causes of the under-performance of European firms in R&D investment. It mainly uses analysis of very recent audited company R&D data to focus on the effects of sectoral structures and business demographics in shaping comparative performance differences between the EU and US.

3. Introduction to benchmarking tools and the data used

This main section starts with a short review of the data used for benchmarking R&D, then centres on the R&D data used in this study (the R&D investment of firms as listed in their annual accounts), introduces their characteristics, and outlines the main differences of the data approach used compared to the OECD's *Frascati* system.

3.1. Introduction to benchmarking data tools

Most R&D analyses are based on official statistics collected according to the procedures outlined in the OECD *Frascati Manual*, which is in effect a global standard for R&D official data collection (OECD, 2002). The *Frascati* approach classifies R&D data on a territorial basis in terms of sources of funding and sectors of expenditure, as well as in terms of socio-economic objectives, research fields and types of research.

However this is not the only way of examining R&D, particularly in the corporate sector, where multiple ways of looking at R&D performance can give differing perspectives on international comparative issues.

Scoreboard rankings are popular tools for benchmarking performance across firms, sectors and countries. In the business world, scoreboards have been used for a long time to compare companies on the basis of market capitalisation[2] or the value of brands.[3] Within innovation studies, two types of scoreboards have emerged: those which construct composite indicators, and those which produce rankings of one selected indicator. Composite scoreboards by definition include multiple indicators and necessarily require some method of combining them to reduce them to a single ranking (Godin, 2002). Since the 1990s, more and improved data on R&D and innovation have become available, for example, through the Community Innovation Survey (CIS, Eurostat, 2007). Such developments have led to the establishment of scoreboards as an increasingly popular measure to compare the performance of countries as a policy-making tool. Examples of these ranking devices are the OECD Technology and Industry Scoreboard,[4] the UK R&D Scoreboard,[5] the US Industrial R&D Leaderboard,[6] and the Australian R&D and Intellectual Property Scoreboards.[7] It is also worth mentioning the European Commission's Innovation Scoreboard which is based on a multi-indicator methodology that provides an annual assessment of innovation performance in the Member States.[8]

However, the geographic coverage, indicators, data sources and methods for data generation for these scoreboards vary, and it is impossible to derive satisfactory comparable information on the distributions and concentrations of *corporate R&D* investment worldwide from the existing national or partially global Scoreboards. It is this consideration which led to the creation of the *EU Industrial R&D Investment Scoreboard* (European Commission, 2008b, for a comparison of Scoreboard and BERD data see Box 1).

Box 1: Comparing the EU R&D Scoreboard with Business Expenditure on R&D (BERD)

The data used for the EU Industrial R&D Investment Scoreboard are different from those provided by statistical offices, e.g. BERD data collected by national statistical agencies. The Scoreboard refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed. The Scoreboard therefore presents an indicator of a particular corporation's global financial commitment to R&D. BERD, on the other hand, refers to all R&D activities performed by businesses within a particular territory (which therefore include small parts of many global businesses), regardless of the location of the business's headquarters, and regardless of the sources of finance. In summary, the distinction between Scoreboard and BERD data can be seen overall as 'global corporate funding' vs. 'activity within a geographical area'.

Furthermore, the Scoreboard collects data from audited financial accounts and reports. BERD typically takes a stratified sample, covering all large companies and a representative sample of smaller ones. Additional differences are regarding the definition of R&D intensity (BERD uses the percentage of value added, while the Scoreboard measures it as the R&D/Sales ratio) and the sectoral classification they use (BERD follows NACE, the European statistical classification of economic sectors, while the Scoreboard classifies companies' economic activities according to the ICB classification).

It is difficult to compare the Scoreboard figures and BERD data directly (European Commission, 2008a). Even if both were fully comprehensive and accurately measured, the global measurements would still differ as BERD includes non-company sources of R&D finance, and because the measurements refer to different samples of firms. Non-company sources for R&D finance can be significant: for example, government-financed BERD is approximately twice as high in the US – both in absolute terms and as a proportion of GDP – compared with the EU 25. This is an important fact that is often overlooked when examining the differences in BERD intensities between the US and the EU (Dosi et al., 2005).

We suggest that both types of measure are useful for policy-makers seeking a complete picture of private R&D investment trends and patterns. The Scoreboard gives policy-makers and others some insight into companies' global R&D commitments and their relationship to firm-level economic outcomes. This focus indicates how much firms, rather than the parts of firms within particular national territories, are investing in R&D and in which industries the most R&D-active companies operate.

3.2. Data and samples selected for the analysis

Data used in this study are collected from the 2008 edition of the EU Industrial R&D Investment Scoreboard[9] (*Scoreboard*). This dataset enables the comparison between large-scale corporate R&D performers in the EU and non-EU world regions. It contains data from the 1000 largest R&D-performing firms in the EU, and the 1000 largest ones in the non-EU world region. The data have been collected from publicly available audited annual reports and accounts of listed, private and state-owned companies in the last reporting year (i.e. 2007/8) and made available as of 29 July 2008.[10]

[2] For example, the FT Global 500 is the *Financial Times* annual snapshot of the world's largest companies by market capitalisation. Market capitalisation is the share price, as recorded, for example, on September 30, 2008, multiplied by the number of shares issued and then converted into the US dollar at that date (see: http://www.ft.com/reports/ft5002008).

[3] Business Week's Global Brands Scoreboard ranks 100 global brands that have a value greater than $1 billion. The brands are global in nature, derive 20% or more of sales from outside their home country and must have publicly available marketing and financial data on which to base the valuation (for 2008 see: http://www.businessweek.com/magazine/content/08_39/b4101052097769.htm).

[4] See OECD (2008) for the last edition of the "OECD Technology and Industry Scoreboard" http://www.oecd.org/document/10/0,3343,en_2649_33703_39493962_1_1_1_1,00.html.

[5] See DIUS (2008). DIUS also publishes a Value Added Scoreboard, ranking the top 800 UK and top 750 European companies by Value Added within industry sector (for 2008 see: http://www.innovation.gov.uk/value_added/).

[6] For 2008 see: Industrial Research Institute: "Industrial Research Institute's 10th Annual R&D Leaderboard", Research Technology Management, pp. 13–17, November–December 2008 (see: http://www.iriinc.org/Template.cfm?Section=RandD_Scoreboard&CONTENTFILEID=2589&TEMPLATE=/ContentManagement/ContentDisplay.cfm).

[7] For 2008 see: http://www.ipria.org/publications/scoreboard.html.

[8] The methodology for the 2008 European Innovation Scoreboard included a stronger focus on services, non-technological aspects, and outputs of innovation, and the analysis of trends over time is now based on changes in the absolute values of the indicators over a 5-year period, rather than the previous approach of measuring trends relative to the EU average. For the 2008 year edition, see http://www.proinno-europe.eu/index.cfm?fuseaction=page.display&topicID=437&parentID=51.

[9] European Commission (2008b).

[10] Data collection was based on the audited reports and accounts as published or as made available by the company upon request. There have been 799 listed and 201 unlisted companies in the EU sample and 956 listed and 44 unlisted companies in the non-EU sample.

As far as individual disclosures are concerned, R&D investment was corrected in order to reflect the share funded by the company itself and its subsidiaries. The *Scoreboard* therefore excludes R&D financed by third parties such as governments or other companies. It also excludes a given company's share of any associated company or joint venture R&D investment, which is listed separately. Where part or all of the R&D costs have been capitalised, the additions to the appropriate intangible assets are included to calculate the cash revenue investment and any amortisation eliminated.

The definitions of R&D used by companies in their audited reports are the same as those described in accepted international accounting standards, specifically IAS 38, in which definitions coincide with those used for official statistics (as set out, for example, in the *Frascati Manual*, OECD, 2002). All monetary amounts were converted to euros.[11]

In the consolidation process, companies that were subsidiaries of another company were excluded to avoid double counting. Majority-owned subsidiaries were consolidated in the accounts of the parent company, whereas joint ventures that were 50% owned by each of two partners were included as stand alone companies.

The classification of the location of a given company depends where (in which country) the ultimate parent company has its registered office. The registered office is the company address notified to the official company registry. It is normally the place where a company's books are kept.

Sector classification is based on the Industrial Classification Benchmark (ICB)[12] system. The *Scoreboard* encompasses 36 out of the 45 ICB sectors, disaggregated at the three-digit level. Classification is based on the companies stating where their main activities lie (see the characterisation of the data sample in Table A1). Taken together, all 2000 *Scoreboard* companies invested a total of €379.3 billion in R&D in 2007/08.

When using the *Scoreboard* data for comparative analyses there are a number of factors that should be taken into account because they potentially affect the interpretation of the figures. In particular, the following points should be noted:

(a) 2008 *Scoreboard* figures are nominal and expressed in euros with all foreign currencies converted at the exchange rate prevailing on 31 December 2007. Financial indicators consolidated from companies' activities in different currency areas are influenced by fluctuations in exchange rates. This has an impact on firms' relative positions in the world rankings based on these indicators. Moreover, the ratios between indicators or the growth rate of an indicator may be affected. For example, the euro appreciated significantly against the US dollar and the pound sterling between 2006 and 2007, rising from $1.32 to $1.46 and from £0.67 to £0.73. This means that the *Scoreboard* underestimates the R&D growth rate of EU companies based in the euro area and operating largely in the US. Conversely the growth rate of US companies with substantial operations in the euro area is overestimated in this case.

(b) Growth in R&D can be organic, due to acquisitions, or a combination of the two. Consequently, mergers and acquisitions may explain sudden changes in the R&D growth rates and rankings of specific companies. They are likely to have less effect on R&D intensities since most acquisitions involve companies in the same sector.

(c) Other important factors to take into account are the difference in the various countries' (or sectors') business cycles that may have a significant impact on companies' investment decisions as well as the adoption of the International Financial Reporting Standards (IFRS).[13] It should be also noted that although the accounting standards lead to a certain standardisation in the data reported, some degree of choice remains for companies as to what may be declared as R&D or not. This can have important impacts.

Finally, it should be pointed out that, for the sake of this study, both the full sets of EU 1000 and non-EU 1000 companies as well as comparable sub-samples of these companies are examined. In fact, the EU 1000 and non-EU 1000 groups include companies with different volumes of R&D investment. For the 2008 edition of the *Scoreboard*, the R&D investment threshold for the EU group is €4.27 million and €24.21 million for the non-EU group. In order to construct sub-samples of comparable EU and non-EU companies, it is preferable to consider only companies with R&D above the non-EU threshold. These groups comprise a set of 402 EU companies, 544 US and 244 Japanese companies, all with R&D of at least €24.2m.

4. The distribution of R&D across sectors

The comparison of R&D intensity data for different groups of sectors selected depending on the level of their R&D intensity follows a widely-used approach to characterise industrial sectors according to their technological activity measured by the level of R&D intensity, i.e. from high to low technological content. The data used here are available in the ICB sector classification. Using R&D over net sales as R&D intensity, the sector classification is matched to the OECD high-technology sector and product classification (OECD, 1997).

The sectors are divided into the following four groups by their average R&D intensity:

Group 1: High R&D intensity sectors (higher than 5%), comprising pharmaceuticals & biotechnology, health-care equipment & services, technology hardware & equipment, software & computer services and leisure goods.
Group 2: Medium-high R&D intensity (between 2% and 5%), comprising automobiles & parts, aerospace & defence, electronics & electrical equipment, industrial engineering & machinery, chemicals, personal goods, household goods, general industrials, support services and travel & leisure.
Group 3: Medium-low R&D intensity (between 1% and 2%), such as food producers, media, oil equipment, general retailers, tobacco, mobile and fixed line telecommunications.
Group 4: Low R&D intensity (below 1%), such as oil & gas, industrial metals, banks, construction & materials, food & drug retailers, beverages, industrial transportation, mining, electricity and multiutilities.

[11] All amounts for all the years reported in each *Scoreboard* are converted at the exchange rates as of 31 December of the reference year. The exchange rates used for the *Scoreboards* may differ from those each company uses in its annual report. As very few companies reveal the exchange rates and geographical distributions of sales or R&D investment, exchange rate effects cannot be avoided. It should be noted that a depreciation of the reporting currency of a firm towards the euro deflates the euro amount that can be taken into account for the Scoreboard and vice versa. For example, all other things being equal, a depreciation of the dollar against the euro would lead to a lower number of US companies entering the EU R&D Scoreboards because the euro amounts of the US companies are deflated by the exchange rate and therefore a smaller number of US companies reach the minimum R&D threshold.

[12] ICB is a definitive equities classification methodology from Dow Jones Indexes and FTSE (more information can be found at the following web page: http://www.icbenchmark.com/).

[13] Since 2005, the European Union has required all listed companies in the EU to prepare their consolidated financial statements according to IFRS (see: Regulation (EC) No 1606/2002 of the European Parliament and of the Council of 19 July 2002 on the application of international accounting standards at http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002R1606:EN:HTML).

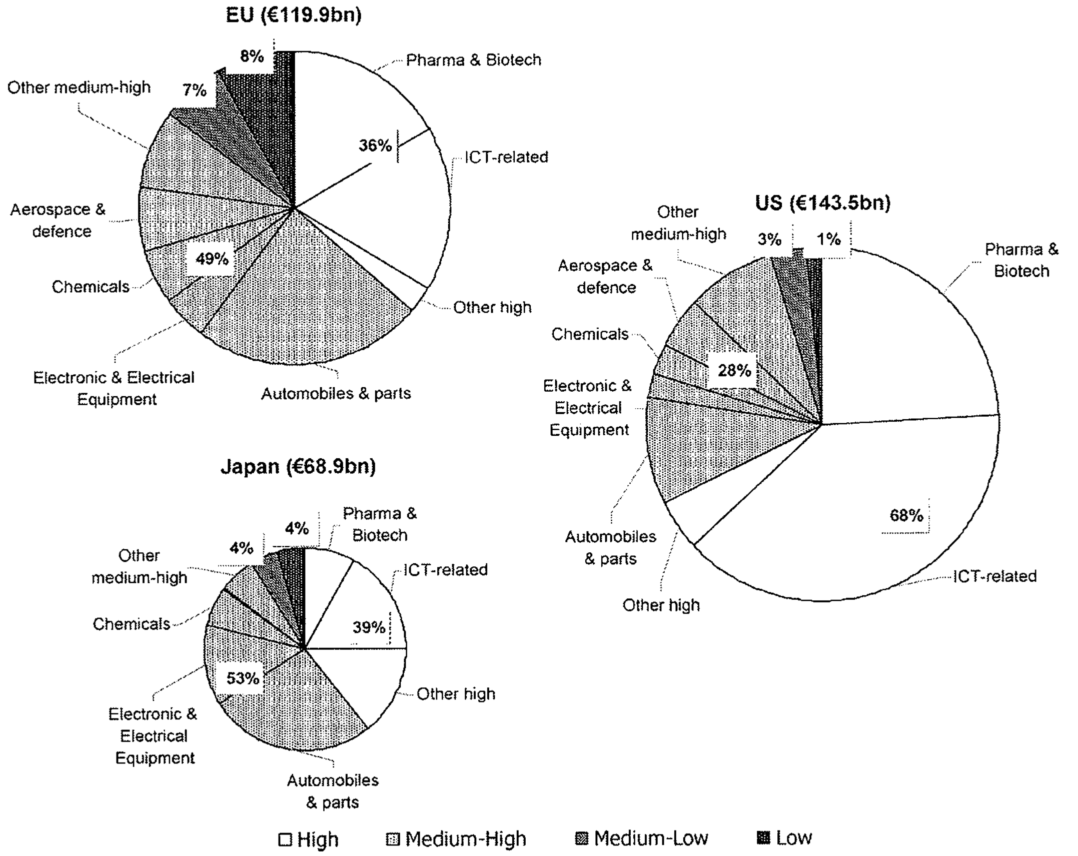

Fig. 1. Shares of R&D investment and the R&D intensity of companies by world region and sectors. *Note*: The size of the circles is approximately proportional to the total amount of R&D investment.
Source: Computed from the EU Industrial R&D Investment Scoreboard data (European Commission, 2008b).

As a first step, the sectoral composition of the EU, the US and Japan by sector group is illustrated below. Fig. 1 comprises the sectoral composition in terms of R&D investment, and Fig. 2 in terms of net sales, so both determinants of *Scoreboard* R&D intensity are covered.

The figures show considerable differences in the sector mix of the three world regions, both in terms of R&D investment and net sales.

Two other figures below take the same concept of sector groups and apply it to compare the R&D intensities of these three world regions.

Figs. 3 and 4 show that considerable differences can also be observed with regard to R&D intensities and net sales in these world regions.

The following conclusions can be drawn from Figs. 1–4 above:

The EU companies have the highest R&D intensity in Group 1 and have R&D intensities comparable to those of the other regions in Groups 2, 3 and 4. However, EU companies have the lowest proportion of total R&D investment in Group 1 (where the US has its highest) and the second highest proportion in Group 2. A consequence of this is the low contribution of high R&D intensity sectors to the overall R&D intensity of the EU. This explains, to a large extent, why the US and Japan both have a much higher R&D intensity than the EU. The latter is also explained by the large size of many of the EU's companies operating in low R&D intensity sectors which account for significantly higher shares of total net sales than total R&D investment.

The US firms invest over two thirds of their total R&D in the high R&D-intensity Group 1 and only 4% in the Medium-low and Low R&D-intensive Groups 3 and 4 and only 28% in Group 2. Thus, in the US, the proportion of R&D investment in Groups 2, 3 and 4 is much lower than for the EU and Japan. This is the main reason for the US companies showing, on aggregate, a much higher R&D intensity than those from the EU and Japan.

Japanese companies concentrate their overall R&D investment in both Group 1 and Group 2. They have a significantly higher R&D intensity than the US companies in Group 2, but this is more than offset by a much lower proportion of total R&D than the US companies in Group 1. This reflects the main weakness of the set of Japanese companies listed in the *Scoreboard* which has a low proportion of companies operating in both pharmaceuticals & biotechnology and software & computer services.

5. Decomposition of R&D intensity

In order to better understand the reason behind the EU's deficit in business R&D intensity, we must consider the relative contributions of the sectoral structure of the economy quantitatively (*structural effect*) vis-à-vis the R&D intensity efforts of firms in each sector (*intrinsic effect*). This comparison has been conducted by considering (a) the non-EU block as the benchmark vis-à-vis the EU and also (b) the US economy as the benchmark vis-à-vis the EU and Japan.

In order to implement the decomposition and calculate the percentage contributions of the two possible reasons behind the total change in R&D intensity in the different economies, we have followed the approach of Haveman and Donselaar (2008), Erken and van Es (2007), Verspagen and Hollanders (1998), and van Velsen

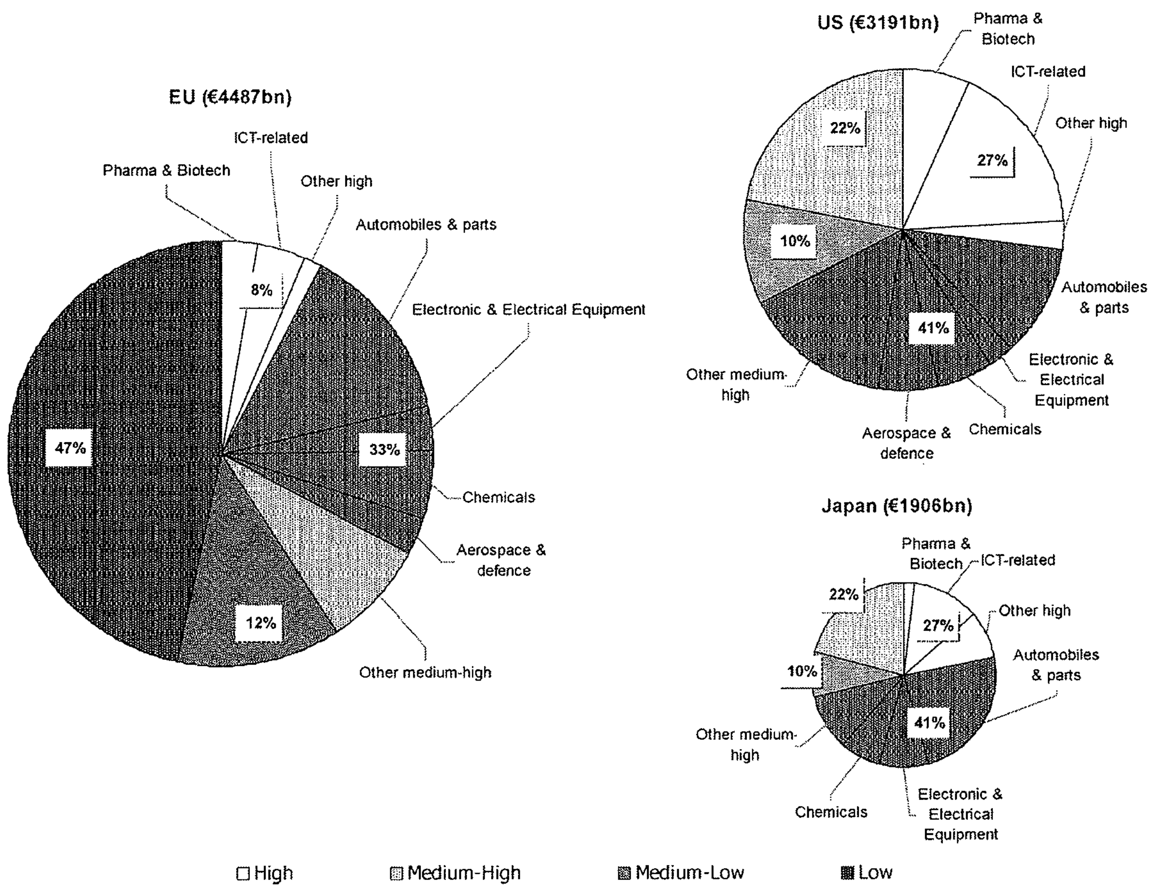

Fig. 2. Shares of net sales and the R&D intensity of companies by world region and sectors. *Note*: The size of the circles is approximately proportional to the total amount of net sales.
Source: Computed from the EU Industrial R&D Investment Scoreboard data (European Commission, 2008b).

(1988). The approach is also similar to that used by van Reenen (1997a,b) who, like van Velsen, uses value added instead of share of industry as a measure of output in a given economy.

The following formula was used for the R&D intensity decomposition (1):

$$\mathrm{RDI}_X - \mathrm{RDI}_Z = \sum_i \mathrm{RDI}_{Z,i}(S_{X,i} - S_{Z,i}) + \sum_i S_{X,i}(\mathrm{RDI}_{X,i} - \mathrm{RDI}_{Z,i}) \quad (1)$$

where

- X refers to one of the two samples to be compared (in our case the EU or the Japanese sample).
- Z is the other sample in the comparison (in our case the non-EU or the US sample).
- RDI stands for R&D intensity (R&D/Y); the value of "Y" is the overall amount of net sales of companies operating in a given sector.

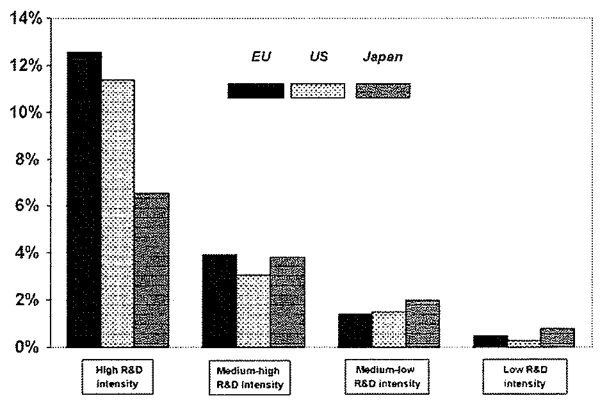

Fig. 3. R&D intensity of Scoreboard companies by sector group and world region.
Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008b).

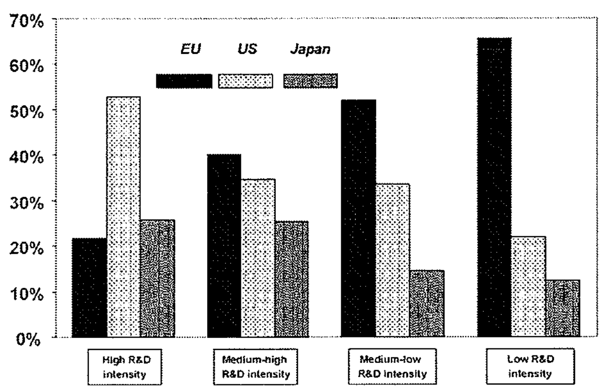

Fig. 4. Shares of net sales of Scoreboard companies by sector group and world region.
Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008b).

- S is the share of the sector i in terms of net sales within a given economy (y_i/Y).

Therefore, the aggregate difference in R&D intensity for a given economy is equal to the sum of the changes in R&D intensity for all sectors over the period, weighted by their average share of net sales over the same period (*intrinsic effect*) plus the sum of the differences in output shares of net sales, weighted by their average intensities (*structural effect*). Thus, if the share of the R&D-intensive industries within the overall economy of *country A* is larger than in *country B*, the structural composition effect is positive for *country A* and negative for *country B*.

We implemented the R&D intensity decomposition calculations also with a comparable subset of these 2000 companies from the EU, US and Japan all with a minimum R&D investment threshold of €24.21 million. This comprises a group of 402 EU companies, representing approximately 95% of total R&D investment by the EU group, and 544 companies and 244 Japanese companies representing 100% of total R&D investment by the these non-EU groups.

Table 1
Total R&D investment and intensity (R&D/Sales) by world region.

	EU-402	US-544	Japan-244	RoW
R&D investment (€ billion)	119.9	143.5	66.9	40.5
R&D intensity (%)	2.7	4.5	3.6	2.6

Source: Computed from the EU Industrial R&D Investment Scoreboard data (European Commission, 2008b).
Note: For possible comparison, the total R&D investment and R&D intensity for the un-truncated sample of company grouping is €126.4 and €253.0 billion for EU-1000 and non-EU 1000 respectively; while the R&D intensity is 2.3% for the EU-1000 and 3.8% for non-EU 1000.

Table 1 below shows the total R&D investment and intensity (R&D as a proportion of net sales) for the *Scoreboard* companies by world region.

The shares of net sales and R&D intensity by sector of 402 EU, 544 US and 244 Japanese companies from the *Scoreboard* dataset are provided in Table 2.

The calculations for the decomposition of R&D intensity have been applied to the EU-402, the US-544 and Japan-244 samples, taking the US-544 as the benchmark. The results are shown in Table 3.

Table 2
Shares of net sales and R&D intensity by sector of 402 EU, 544 US and 244 Japanese companies from the *Scoreboard*.

4-digit ICB code	4-digit ICB sector in the *Scoreboard*	EU-402		US-544		Japan-244	
		Share of sales	R&D intensity	Share of sales	R&D intensity	Share of sales	R&D intensity
353	Beverages					0.92%	1.30%
357	Food producers	2.16%	1.73%	2.91%	0.87%	1.08%	2.30%
378	Tobacco	0.30%	1.19%	1.15%	1.28%	1.53%	0.86%
173	Forestry & paper	1.01%	0.55%	0.36%	0.42%	0.78%	0.75%
555	Media	1.00%	2.60%	1.28%	0.56%	1.00%	1.83%
177	Mining	1.58%	0.32%			0.46%	0.69%
53	Oil & gas producers	16.31%	0.30%	15.89%	0.21%	3.35%	0.22%
57	Oil equipment, services & distribution	0.39%	0.83%	1.82%	2.24%		
135	Chemicals	5.29%	2.86%	5.38%	2.40%	7.05%	3.17%
376	Personal goods	1.10%	1.68%	1.15%	1.72%	0.77%	2.88%
4573	Biotechnology	0.10%	21.42%	0.83%	26.76%	0.11%	9.41%
4577	Pharmaceuticals	2.75%	15.51%	5.70%	15.25%	1.75%	16.27%
235	Construction & materials	3.02%	0.69%	0.83%	1.00%	4.19%	1.13%
175	Industrial metals	3.76%	0.47%	0.70%	1.15%	4.79%	1.05%
272	General industrials	1.23%	2.84%	6.10%	2.37%	2.38%	2.76%
372	Household goods	1.12%	2.28%	2.82%	2.46%	1.55%	1.17%
2757	Industrial machinery	2.29%	2.80%	1.00%	1.74%	1.70%	2.59%
9572	Computer hardware	0.03%	5.60%	5.44%	4.70%	7.49%	5.18%
9574	Electronic office equipment	0.09%	6.65%	0.49%	4.22%	1.15%	5.70%
9576	Semiconductors	0.57%	16.85%	3.15%	16.41%	1.03%	6.64%
2733	Electrical components & equipment	3.06%	3.43%	1.27%	1.83%	3.52%	3.66%
2737	Electronic equipment	0.35%	5.68%	1.13%	5.99%	5.37%	6.30%
374	Leisure goods	0.69%	5.90%	0.82%	7.78%	8.15%	6.23%
9578	Telecommunications equipment	2.04%	13.04%	2.49%	12.76%	0.23%	2.96%
453	Health-care equipment & services	0.71%	4.36%	1.89%	7.81%	0.23%	5.63%
335	Automobiles & parts	13.63%	4.68%	11.34%	3.90%	23.58%	4.07%
2753	Commercial vehicles & trucks	1.54%	3.54%	2.93%	2.66%	1.21%	2.90%
271	Aerospace & defence	2.71%	6.57%	6.18%	3.33%	0.04%	6.09%
753	Electricity	3.60%	0.74%			4.97%	0.68%
757	Gas, water & multiutilities	5.38%	0.21%	0.08%	1.68%	0.82%	0.79%
533	Food & drug retailers	1.97%	0.33%	4.07%	0.28%	0.47%	0.38%
537	General retailers	2.62%	0.36%	0.48%	7.45%		
575	Travel & leisure	0.22%	0.89%	0.39%	3.34%	1.47%	1.90%
653	Fixed line telecommunications	5.76%	1.64%	2.55%	0.83%	3.46%	2.53%
277	Industrial transportation	1.82%	0.31%				
657	Mobile telecommunications	1.08%	0.66%			1.07%	0.46%
835	Banks	6.19%	0.95%	0.85%	0.92%		
857	Life insurance	0.83%	0.40%				
853	Nonlife insurance	0.20%	0.79%				
877	Other financials	0.25%	2.37%	0.05%	10.06%		
279	Support services	0.38%	2.40%	0.50%	3.39%	0.61%	1.28%
9533	Computer services	0.41%	3.08%	2.60%	5.39%	1.74%	4.79%
9535	Internet			0.55%	13.91%		
9537	Software	0.47%	15.52%	2.82%	14.78%		
	Grand total	100%	2.67%	100%	4.50%	100%	3.62%

Source: Computed from the EU Industrial R&D Investment Scoreboard data (b).

Table 3
Decomposition of R&D intensities for the sample of 402 EU, 544 US and 244 Japanese companies from the *Scoreboard*.

	Difference in R&D intensity from US-544	of which structural effect	of which intrinsic effect
EU-402	−1.80	−1.84	0.05
Japan-244	−0.35	−0.37	0.02

Source: Computed from the EU Industrial R&D Investment Scoreboard data (European Commission, 2008b).

The calculations for the EU 402 vs. the US 544 sample show that the intrinsic effect is only slightly positive. Furthermore, the overall EU R&D intensity gap is entirely due to the structural effect. A similar observation, but with less significance, can be found for the 244 Japanese companies compared to the 544 US ones.

We have also implemented the same decomposition calculation using the full set of companies, i.e. 1000 EU vs. 1000 non-EU samples.[14] It results in a difference in R&D intensity of −1.53, of which −1.19 is due to structural and −0.34 is due to intrinsic effects. This decomposition for the EU-1000 vs. the non-EU1000 sample reveals that only around one fifth (22.2%) of the R&D intensity gap is due to the intrinsic effect.

Thus, the decomposition calculated for the un-truncated samples shows a less pronounced dominance of the structural effect than the one seen for the EU 402 vs. the US 544. However, in the EU-1000 vs. non-EU-1000 comparison, a size bias intervenes resulting in the slightly lower dominance of the structural effect, as the non-EU sample in this case is bigger in size and therefore more R&D intensive than the EU one.

By and large, our analyses do not indicate a systematic underinvestment in R&D by the companies in the EU samples (EU-402 and EU-1000) compared to those in the US-544, Japanese-244 or in the overall non-EU-1000 sample given the sectors they are in. Rather, they confirm the big differences in sector mix that exists between these three economies.

These results differ from those of other R&D decomposition analyses (Erken and van Es, 2007; ETEPS, 2007; Pianta, 2005; Dosi, 1997; van Reenen, 1997a,b) based on BERD/OECD-STAN data.[15] In our opinion, the main reason for dissimilar results can be attributed to the methodological heterogeneity (as pointed out in Section 3.1) between the datasets and statistical sources. In addition, comparing the decompositions of R&D intensity using Scoreboard data and BERD can be more problematic because of other weaknesses affecting both datasets. For example, there could be a systematic overestimation of the role of the intrinsic effect in the EU/US comparison in the BERD/OECD-STAN data due to the significantly overestimated service R&D expenditure in the US compared to the EU (Duchêne et al., 2009). On the other hand, *Scoreboard* companies classified in one sector in many cases have significant operations in others (e.g. IBM, Philips, Siemens). In addition, the *Scoreboard* companies – and their R&D investment – are allocated to the country of registered office, while the execution of their R&D investment may be spread over several other countries. Most large multinationals now find it necessary to place some of their R&D in each of the three main world regions – the EU, North America and Asia Pacific. Nevertheless, a company with its registered office and headquarters in one region is likely to take decisions in that region on the shape of its global business and its R&D strategy and intensity. Finally, one might argue that the *Scoreboard* dataset has a sample bias affecting the results because it only represents the top R&D investors (*picking winners*). However, this argument does not appear to be

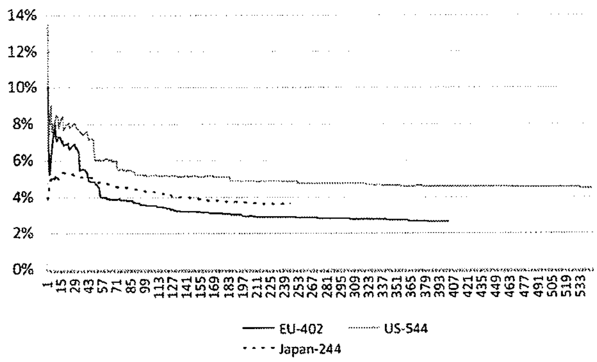

Fig. 5. Cumulated average R&D intensity of the examined samples of 402 EU, 544 US and 244 Japanese companies in 2007 (%). *Note*: Cumulative average R&D intensity is calculated by summing the R&D investment from the largest to the smallest R&D investor in the group and dividing by cumulative sales. The figure plots the average R&D intensities for each group of *n* top companies from largest to smallest R&D investor against the number of companies. As there are only 244 Japanese companies in the sample we analysed, the graph for Japanese companies stops at 244 on the horizontal axis, while it goes up to 402 for the set of EU companies and 544 for the US companies.
Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008b).

convincing since the 1000 EU and the1000 non-EU companies altogether represent approximately 80% of business expenditure on R&D worldwide.[16] While non-R&D investors were excluded in the screening process, where the accounts of 5913 companies were examined for R&D activity, the objective of the present study is not to examine the structure of the whole economy, but to focus on the structure of R&D investment for the private sector. When investigating the structure of R&D investment in the main private R&D investing world regions (i.e. EU, US and Japan), the potential activity of smaller R&D investors is much less significant.

6. Distribution of R&D across top R&D investing firms

The previous section has provided further evidence that the sources of differences in EU R&D investment performance lie primarily in the structural effect and that the intrinsic effect has only a minor influence. In order to analyse this further, we examine cumulative average R&D intensity by company size and world region (see Fig. 5 below).

This figure shows that corporate R&D is asymmetrically distributed with a significant difference in the degree of concentration between EU and non-EU sets of companies. This suggests that differences in overall R&D intensities also reflect business demographics. Moving down the rankings, there is a large population of smaller US companies that invests more strongly in R&D, and in a more consistent way than the EU companies, thus raising the overall R&D performance of the United States. US firms are per-

[14] Appendix A provides information of the shares of net sales and R&D intensity by sector of EU-1000 and non-EU-1000 companies from the 2008 *Scoreboard*.

[15] The decomposition based on OECD/STAN data showed more than 80% of the R&D intensity difference between the EU and the US due to *intrinsic* effects (ETEPS, 2007).

[16] BERD figures on global business R&D expenditure comparable to the 2008 *Scoreboard* figures were not yet available when this article was written. The figure here is an extrapolation from the comparison of Scoreboard data since 2004 with Eurostat BERD figures and growth rates until 2007. The exact calculation is replicated in European Commission (2008b), p. 12.

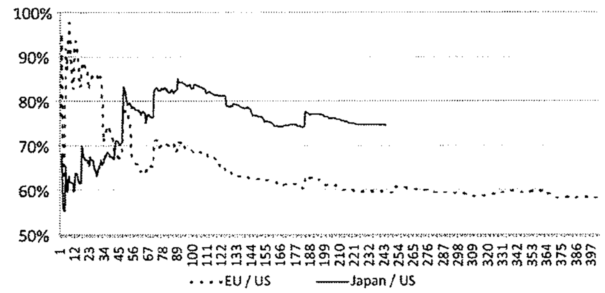

Fig. 6. Ratio of cumulative R&D investment of the examined samples of 402 EU and 244 Japanese companies as compared to the 544 US companies in 2007 (%). *Note*: The ratio for the top *n* EU companies as compared to the top *n* US companies is computed by dividing the cumulated R&D investment of *n* EU companies by the cumulated R&D investment of the same number of top US companies. The same applies to Japanese companies as compared to US companies. As there are only 244 Japanese companies in the sample we analysed, the graph for Japanese companies stops at 244 on the horizontal axis, while it goes up to 402 for the set of EU companies.
Source: Computed from the "EU Industrial R&D Investment Scoreboard" (European Commission, 2008b).

forming considerably more R&D at smaller firm-size levels. One reason that could explain this observation is that these companies are concentrated in sectors that are intrinsically more R&D intensive.

It is also clear that the very big R&D investors are more R&D intensive than the smaller ones. For both the US and EU, the cumulative average R&D intensities fall sharply before the 47th and the 30th company respectively and then flatten off. Moreover, the cumulative R&D intensity drops sharply at particular points due to the sudden inclusion in the list of several large companies with very low R&D intensity.

The gap in R&D intensity between the EU and US companies is much smaller amongst the first 30 companies in each set than later on, and the EU companies have an even higher cumulative average R&D intensity than the Japanese ones for the first 40 companies. However, after these points, there is a much smaller proportion of high R&D intensity companies in the EU sample and this increases the gap in cumulative average R&D investment. This means that not only is R&D activity more concentrated amongst the bigger companies in the EU sample than in the others, but also that in the EU sample there are more large R&D-investing companies with very low R&D intensity. Examples of EU companies with very large sales compared to their R&D investment are Total, BP, Shell, Electricité de France and ENI.

Fig. 6 illustrates the relative concentration of R&D investment for the EU and Japanese samples compared to the US sample in terms of cumulative average of R&D investment. The ratio used is the cumulative R&D investment of the top company, then the top 2 companies, continuing up to the maximum number of companies in the EU and Japanese samples, each divided by the corresponding sum for the same number of US companies. Therefore, Fig. 6 has a horizontal axis showing the number of companies (maximum 402 for the EU and 234 for the Japanese sample), with R&D investment of US companies taken as the denominator and a vertical axis showing the ratio between the cumulative R&D investments of a similar number of companies in any pair of two of the three major regions.

The top 32 companies in the EU sample have more than 80% of the R&D investment of their US counterparts, with the EU/US ratio oscillating between 62% and 98%. The overall trend of the curve for the EU vs. the US companies is downwards. It is again companies with very big sales compared to their R&D investment, like those mentioned above, that bring the cumulative ratio down.

A different pattern is observed for the Japanese vs. US companies. The curve is climbing at the very beginning, reaching 84% after 91 companies. A number of Japanese companies in high R&D intensity sectors, e.g. Advantest, Taisho Pharmaceuticals or Tanabe Seiyaku (now Mitsubishi Tanabe Pharma), is responsible for this. After that, the trend in the curve for Japanese vs. US companies is downward, running in parallel with the EU vs. US curve, but at a higher level. This underlines the role of business demographics when measuring overall average R&D intensities: moving down the rankings, there is a sizeable population of US companies that invests more strongly in R&D, and in a more consistent way than the EU companies, thus raising the overall R&D performance of United States. US firms are performing considerably more R&D at lower firm-size levels, not least due to a concentration of these companies in sectors that are intrinsically R&D intensive.

In turn, the role of R&D in small and medium sized enterprises (SMEs) is crucial in transforming an SME into a fast growing company. While some SMEs are potentially innovative and ready to grow, others are revolving-door firms which stay on the fringe of an industry for a while with no chance of entering its core and are doomed to exit the market. However, according to Ortega-Argilés et al. (2009b), the positive growth process is frequent only in technologically-advanced countries. Therefore, SME growth could depend very much on the specific country, sector and technology under consideration.

7. Conclusions and policy issues

Targets for R&D intensity or expenditure are appealing and apparently easy to grasp, but they are even more easily misunderstood because the overall R&D 'effort' is the result of a combination of firm strategies, company demographics, industrial structures, and macro-economic dynamics. Given their widespread use and ever-increasing importance for both policy-making and the measurement of competitiveness, it is necessary to increase our knowledge about these composite indicators by understanding their structure using a methodologically sound approach and a reliable dataset.

Aggregate R&D performance is affected by a wide range of factors, including industrial structures, company demographics, relative fiscal and monetary stances, business cycles, and corporate strategies.

This paper has examined the cause of the overall EU/US R&D investment intensity gap by investigating two possible determining factors: the effect of the sector composition (structural effect) vis-à-vis the intensity of R&D in each sector (intrinsic effect) together with the role of company demographics in R&D investment.

The data used in this study show that there are two basic reasons why EU-1000 firms have a lower aggregate R&D intensity than non-EU 1000 firms.

The first and major one is the difference in the sectoral distribution among these firms, with the EU having a stronger specialisation in automobiles and parts, and a much weaker specialisation in IT hardware, electronics and software.

Our decomposition of the overall R&D intensity gap between the EU and the non-EU world regions, the EU vs. the US and Japan vs. the US into a structural and an intrinsic effect has shown that structural differences between economies explain almost all of this gap.

The second reason – related to the first, but not determined by it – is a difference in company populations: this analysis points out that there is not a very big underinvestment gap by individual EU companies with respect to the US and Japanese ones for companies at the very top of the global R&D ranking. However, a substantial proportion of business R&D is carried out by a relatively small number of EU firms which perform large volumes of R&D; this is in contrast to the US firms where there is a more broadly spread distribution of the level of R&D investment intensity across companies. Thus, this sub-population of firms may be a target for public policies aimed at increasing the levels and intensities of R&D in the EU.

There is disagreement about the policy significance of structural effects in R&D intensity. Jaumotte and Pain (2005) argued that structural effects are of little relevance because "the policy implications would be unclear, especially for governments seeking to raise the aggregate rate of R&D intensity". Even where a role of sectoral specialisation for R&D investment is found, the picture beyond structural specialisation towards its determining factors with their links to R&D investment behaviour is very unclear (Mathieu and van Pottelsberghe de la Potterie, 2008).

Our view is that difficulty in identifying implications does not mean that they are unimportant. On the contrary, we suggest that structural effects raise important issues about the appropriate focus of policy analyses. Given the pervasive effects of these structural differences, one way of approaching the R&D policy debate in Europe would be to say that its implicit sub-text is a concern with Europe's industrial structure. This is almost never discussed openly in Europe (or anywhere else, for that matter), although Dosi et al. (2005) suggest in passing that it ought to be focused on explicitly.

Does this mean that policy should consist of an attempt to emulate the industrial structures of Japan and the US? Actually that *is* in fact what policy has consisted of in many EU countries, and throughout the OECD. Despite the ostensible rejection of industrial policy measures based on support for specific industries, many OECD countries have adopted R&D policies that closely support sectors such as ICT, pharmaceuticals and aerospace: it is almost impossible to find an OECD country with public R&D policies that are not focused on some combination of these R&D fields (usually combined with nanotechnology, which is not yet the basis of a sizeable industry). These R&D policies are quasi-industrial policies, in the sense that they seek to use R&D policy to support the growth of certain industries, thus shifting industrial structures towards so-called high-technology areas.

Yet it is far from clear whether industrial structures can in fact be an object of policy in this way. There are two broad issues here. One is that the non-EU advantage in R&D intensity depends not on R&D in itself but on a much stronger record of company creation and growth, especially of mid-size companies, in ICT and related sectors. The US in particular has demonstrated an ability to create, sustain and grow a much wider array of companies, across a broader range of activities within ICT, than the EU has. Therefore, the most important issue should be the factors that facilitate this, and these are likely to extend well beyond R&D performance. They include the creation of a variety of technological opportunities, the ability to initiate new ventures, and the ability to finance the long-term growth of firms. Any policy attempting to emulate US capabilities in firm creation would have to address the underlying issues of opportunity recognition, finance, risk management, and the like, which lead not only to business creation but also to more rapid business growth. A second, much more difficult question is whether such an effort would be justified at all. An interesting characteristic of those who regard Europe as a failure in terms of R&D performance (and other areas of S&T performance) is that they simply assume that growth is shaped by R&D inputs in ICT, biotech, etc., and rarely discuss the wider dimensions of EU vs. non-EU economic performance. The real issue is not an idealised industrial structure, but how actual industrial structures (which as we have seen differ markedly) perform in terms of macro-economic stability, sustainability of growth, innovation, employment quality, productivity, income and wealth distribution, access to services, government budgetary performance or external balances. Relating such performance outcomes to industrial structures would require widening the focus of innovation analysis away from R&D inputs, and exploring how different forms of innovation – product, manufacturing, business process and service – may occur across industries; this would require a focus on the innovation performance of industries that use non-R&D inputs to innovation, and more generally on the innovation and growth characteristics of low-R&D intensity industries (Hirsch-Kreinsen et al., 2005). Our analysis suggests that it is time to shift the debate towards issues such as industrial and business creation and sustainable growth, and to explore the often unexpected economic outcomes of different industrial and business structures. This is a complex challenge, but an increasingly urgent policy issue.

As long as R&D is understood as one of the relevant inputs to economic growth, along with increasing skilled employment and competitiveness, R&D intensity targets will remain common in the policy sphere. However, policy-makers should become more aware of the appropriate focus of policy analysis and its implications: our decomposition shows that these may lead to possible shifts towards more knowledge-intensive sectors of the economy.[17] At the same time, it is auspicious to favour the organic, R&D-led growth of smaller companies in new, emerging sectors in an attempt to enhance the future competitiveness of the EU in the global economy.

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Appendix A. Tables characterising the Scoreboard dataset

See Tables A1–A3 .

[17] There are examples of successful policies that helped shift the economic structure, e.g. the Bayh-Dole Act, an antitrust legislation facilitating the entry of new firms which has succeeded in changing the US pattern of specialisation towards the new, R&D-intensive technologies.

Table A1
Characterisation of the data sample.

4-digit ICB code	Sum of R&D Investment 2007 Sector name 4-digit ICB	Number of companies	EU	Number of companies	Non-EU	Grand total
271	Aerospace & defence	24	8093.89	26	7134.15	15,228.04
58	Alternative energy	1	17.20			17.2
335	Automobiles & parts	45	28,781.21	55	34,644.82	63,426.03
835	Banks	23	2734.85	1	38.92	2773.77
353	Beverages	4	63.79	3	476.85	540.64
4573	Biotechnology	67	1506.93	62	7912.61	9419.54
135	Chemicals	45	7066.54	74	9634.10	16,700.64
2753	Commercial vehicles & trucks	17	2533.26	18	3669.79	6203.05
9572	Computer hardware	9	163.88	49	16,673.40	16,837.28
9533	Computer services	22	688.05	13	6294.53	6982.58
235	Construction & materials	29	1129.63	20	1362.31	2491.94
2733	Electrical components & equipment	35	4917.05	29	4816.44	9733.49
753	Electricity	21	1387.35	11	1197.82	2585.17
2737	Electronic equipment	37	1206.46	64	15,627.91	16,834.37
9574	Electronic office equipment	2	266.35	5	1913.46	2179.81
653	Fixed line telecommunications	15	4309.70	7	3626.12	7935.82
533	Food & drug retailers	5	331.47	3	391.01	722.48
357	Food producers	35	1888.68	17	2467.28	4355.96
173	Forestry & paper	7	275.36	3	160.01	435.37
757	Gas, water & multiutilities	10	560.98	3	168.57	729.55
272	General industrials	23	1698.81	28	6557.40	8256.21
537	General retailers	17	525.22	3	1180.23	1705.45
453	Health-care equipment & services	32	1541.67	46	5166.60	6708.27
372	Household goods	24	1274.29	18	2577.85	3852.14
2757	Industrial machinery	75	3402.13	35	2051.84	5453.97
175	Industrial metals	12	842.63	17	1680.41	2523.04
277	Industrial transportation	14	367.79			367.79
9535	Internet	3	41.20	9	2552.12	2593.32
374	Leisure goods	8	1843.49	24	11,929.94	13,773.43
857	Life insurance	3	171.69			171.69
555	Media	15	1296.82	8	577.23	1874.05
177	Mining	6	251.86	3	561.20	813.06
657	Mobile telecommunications	2	324.27	4	403.62	727.89
853	Nonlife insurance	8	139.72			139.72
53	Oil & gas producers	11	2220.07	15	3543.41	5763.48
57	Oil equipment, services & distribution	9	207.67	9	1303.11	1510.78
877	Other financials	19	415.68	3	170.45	586.13
376	Personal goods	21	981.15	13	1511.16	2492.31
4577	Pharmaceuticals	61	19,413.83	65	43,466.12	62,879.95
9576	Semiconductors	22	4447.92	102	20,626.23	25,074.15
9537	Software	85	3893.23	68	13,916.61	17,809.84
279	Support services	33	654.83	10	900.80	1555.63
9578	Telecommunications equipment	27	12,107.15	42	12,367.17	24,474.32
378	Tobacco	2	170.70	3	723.05	893.75
575	Travel & leisure	15	201.93	12	1007.12	1209.05
	Grand total	1000	126,358.38	1000	252,983.77	37,9342.2

Source: Computed from the "EU Industrial R&D Investment Scoreboard" (European Commission, 2008b).

Table A2
Shares of net sales and R&D intensity by sector in the 1000 EU and 1000 non-EU *Scoreboard* sample.

4-digit ICB sector code	4 digit ICB sector name	EU		Non-EU	
		Share of sales	R&D intensity	Share of sales	R&D intensity
5	Beverages	0.82%	0.14%	0.67%	1.07%
19	Food producers	2.55%	1.34%	2.80%	1.33%
48	Tobacco	0.27%	1.14%	0.99%	1.10%
20	Forestry & paper	0.98%	0.51%	0.40%	0.60%
32	Media	1.14%	2.07%	0.90%	0.96%
33	Mining	1.32%	0.35%	0.46%	1.82%
37	Oil & gas producers	14.34%	0.28%	15.46%	0.35%
38	Oil equipment, services & distribution	0.44%	0.85%	0.88%	2.24%
7	Chemicals	4.64%	2.76%	5.25%	2.76%
40	Personal goods	1.04%	1.71%	0.92%	2.46%
6	Biotechnology	0.10%	26.02%	0.48%	25.03%
41	Pharmaceuticals	2.84%	12.40%	4.27%	15.34%
11	Construction & materials	3.80%	0.54%	1.72%	1.19%
27	Industrial metals	3.41%	0.45%	2.66%	0.95%
22	General industrials	1.47%	2.09%	5.11%	1.93%
25	Household goods	1.11%	2.08%	1.80%	2.15%
26	Industrial machinery	2.39%	2.58%	1.53%	2.02%
9	Computer hardware	0.04%	7.59%	5.85%	4.29%

Table A2 (*Continued*)

4-digit ICB sector code	4 digit ICB sector name	EU		Non-EU	
		Share of sales	R&D intensity	Share of sales	R&D intensity
15	Electronic office equipment	0.07%	6.65%	0.57%	5.08%
44	Semiconductors	0.48%	16.73%	2.27%	13.70%
12	Electrical components & equipment	2.61%	3.42%	2.34%	3.11%
14	Electronic equipment	0.44%	4.97%	4.95%	4.76%
30	Leisure goods	0.57%	5.86%	2.86%	6.28%
47	Telecommunications equipment	1.69%	12.96%	1.56%	11.93%
24	Health-care equipment & services	0.60%	4.62%	1.03%	7.54%
3	Automobiles & parts	11.25%	4.64%	13.51%	3.86%
8	Commercial vehicles & trucks	1.33%	3.46%	2.20%	2.51%
1	Aerospace & defence	2.29%	6.40%	3.31%	3.25%
2	Alternative energy	0.02%	2.00%		
13	Electricity	3.97%	0.63%	2.00%	0.90%
21	Gas, water & multiutilities	4.75%	0.21%	0.28%	0.92%
18	Food & drug retailers	2.43%	0.25%	2.09%	0.28%
23	General retailers	3.77%	0.25%	0.31%	5.70%
49	Travel & leisure	2.06%	0.18%	0.62%	2.46%
17	Fixed line telecommunications	5.04%	1.55%	3.05%	1.79%
28	Industrial transportation	2.07%	0.32%		
34	Mobile telecommunications	0.88%	0.67%	0.62%	0.98%
4	Banks	5.84%	0.85%	0.06%	0.98%
31	Life insurance	0.93%	0.34%		
36	Nonlife insurance	1.62%	0.16%		
39	Other financials	0.82%	0.92%	0.03%	7.48%
46	Support services	0.89%	1.34%	0.64%	2.13%
10	Computer services	0.39%	3.17%	1.80%	5.25%
29	Internet	0.00%	39.43%	0.28%	13.75%
45	Software	0.47%	14.95%	1.45%	14.46%
	Grand total	100.00%	2.29%	100.00%	3.81%

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008b).

Table A3
R&D intensity of Scoreboard companies by sector group and world region.

R&D intensity	EU	USA	Japan	RoW
High	12.6%	11.4%	6.5%	8.5%
Medium high	3.9%	3.1%	3.8%	2.6%
Medium low	1.4%	1.5%	1.9%	1.9%
Low	0.5%	0.3%	0.8%	0.7%

Source: Computed from the EU Industrial R&D Investment Scoreboard (European Commission, 2008b).

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